



Ambient Groundwater Quality of the Tonto Creek Basin

A 2002-2012 Baseline Study – November 2013
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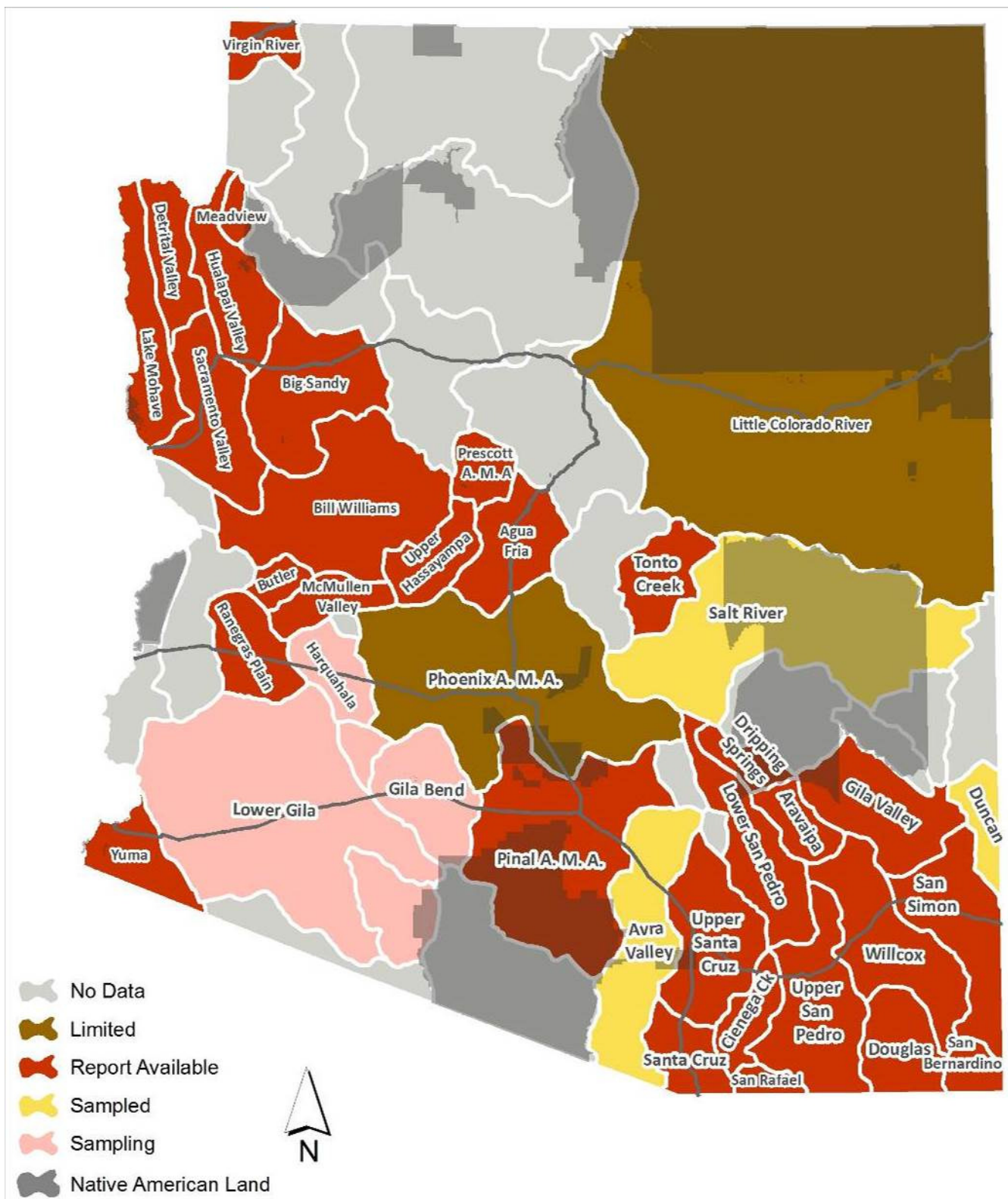
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Thanks:

Field Assistance: Elizabeth Boettcher, Susan Determann, Jade Dickens, Joe Harmon, Angela Lucci, and Joanie Rhyner. Special recognition is extended to the many well owners who were kind enough to give permission to collect groundwater data on their property.

Photo and Map Credits: Douglas Towne

Report Cover: Clover Well consists of a windmill, storage tank, and pipelines transporting water to troughs for livestock use. The windmill is located west of the community of Rye at the base of the Mazatzal Mountains in the Tonto Creek Basin.



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Abbreviations

| | |
|--------------------|--------------------------------------------------------------------------------------------------------------|
| amsl | above mean sea level |
| ac-ft | acre-feet |
| af/yr | acre-feet per year |
| ADEQ | Arizona Department of Environmental Quality |
| ADHS | Arizona Department of Health Services |
| ADWR | Arizona Department of Water Resources |
| ARRA | Arizona Radiation Regulatory Agency |
| AZGS | Arizona Geological Survey |
| As | arsenic |
| bls | below land surface |
| BLM | U.S. Department of the Interior Bureau of Land Management |
| CAP | Central Arizona Project |
| °C | degrees Celsius |
| CI _{0.95} | 95 percent Confidence Interval |
| Cl | chloride |
| EPA | U.S. Environmental Protection Agency |
| F | fluoride |
| Fe | iron |
| gpm | gallons per minute |
| GWPL | Groundwater Protection List active ingredient |
| HCl | hydrochloric acid |
| LLD | Lower Limit of Detection |
| Mn | manganese |
| MCL | Maximum Contaminant Level |
| ml | milliliter |
| msl | mean sea level |
| ug/L | micrograms per liter |
| um | micron |
| uS/cm | microsiemens per centimeter at 25° Celsius |
| mg/L | milligrams per liter |
| MRL | Minimum Reporting Limit |
| ns | not significant |
| ntu | nephelometric turbidity unit |
| pCi/L | picocuries per liter |
| QA | Quality Assurance |
| QAPP | Quality Assurance Project Plan |
| QC | Quality Control |
| SAR | Sodium Adsorption Ratio |
| SDW | Safe Drinking Water |
| SC | Specific Conductivity |
| su | standard pH units |
| SO ₄ | sulfate |
| TDS | Total Dissolved Solids |
| TKN | Total Kjeldahl Nitrogen |
| TON | Tonto Basin Groundwater Basin |
| USFS | U.S. Forest Service |
| USGS | U.S. Geological Survey |
| VOC | Volatile Organic Compound |
| WQARF | Water Quality Assurance Revolving Fund |
| * | significant at $p \leq 0.05$ or 95% confidence level |
| ** | significant at $p \leq 0.01$ or 99% confidence level |
| *** | for information only, statistical test for this constituent invalid because detections fewer than 50 percent |

Ambient Groundwater Quality of the Tonto Creek Basin: A 2002-2012 Baseline Study

Abstract - From 2002-2012, the Arizona Department of Environmental Quality conducted a baseline groundwater quality study of the Tonto Creek basin located approximately 40 miles northeast of Phoenix. The basin comprises 955 square miles within Gila County and includes the communities of Gisela, Kohl's Ranch, Punkin Center, Rye, and Star Valley. The basin consists of rugged mountains formed by faulting and trends north-south. Low-intensity livestock grazing and recreational activities are the main land uses. Land ownership consists of federal land (97.5 percent) managed by the U.S. Forest Service as part of the Tonto National Forest. The remainder is private inholdings (2.4 percent) and Tonto Apache tribal lands (0.1 percent).³ The basin is drained by Tonto Creek which heads just below the Mogollon Rim near Kohl's Ranch and exits the basin about eight miles south of Punkin Center to later enter Theodore Roosevelt Lake, contributing an annual average discharge of 105,000 acre-feet.⁴ Major perennial tributaries include Rye, Spring, Haigler, Dell Shay, Houston, Christopher, and Greenback creeks.

Groundwater occurs in the Tonto Creek basin in four geologic categories: stream alluvium, basin-fill sediments, Paleozoic sedimentary rocks, and Precambrian igneous, metamorphic, and sedimentary rocks. The primary aquifer is the unconsolidated sediments including stream alluvium (along Tonto Creek and its major tributaries) and basin fill that underlie much of the basin south of Rye. Paleozoic sedimentary rocks along the Mogollon Rim can also produce abundant water from a limestone aquifer whose source is the C-aquifer in the adjacent Little Colorado River basin. Precambrian igneous, metamorphic, and sedimentary rocks in the basin's margins sometimes produce limited groundwater.^{4, 10, 21} Groundwater is used for all municipal and domestic uses and most irrigation and stock uses in the basin. Small diversions on Tonto Creek and its tributaries supply surface water for irrigation such as near Gisela.

Thirty-one sites (20 wells and 11 springs) were sampled for the study. Inorganic constituents were collected at each site while radionuclide (19), oxygen and deuterium isotopes (10), volatile organic compounds or VOCs (8), and radon (5) samples were collected at selected sites. Of the 31 sites sampled, 22 sites met all drinking water quality standards not including the proposed radon standard. Of the five sites sampled for radon, none exceeded the proposed 4,000 picocuries per liter (pCi/L) standard while all five sites (100 percent) exceeded the proposed 300 pCi/L standard.²⁶ There were no VOC detections.

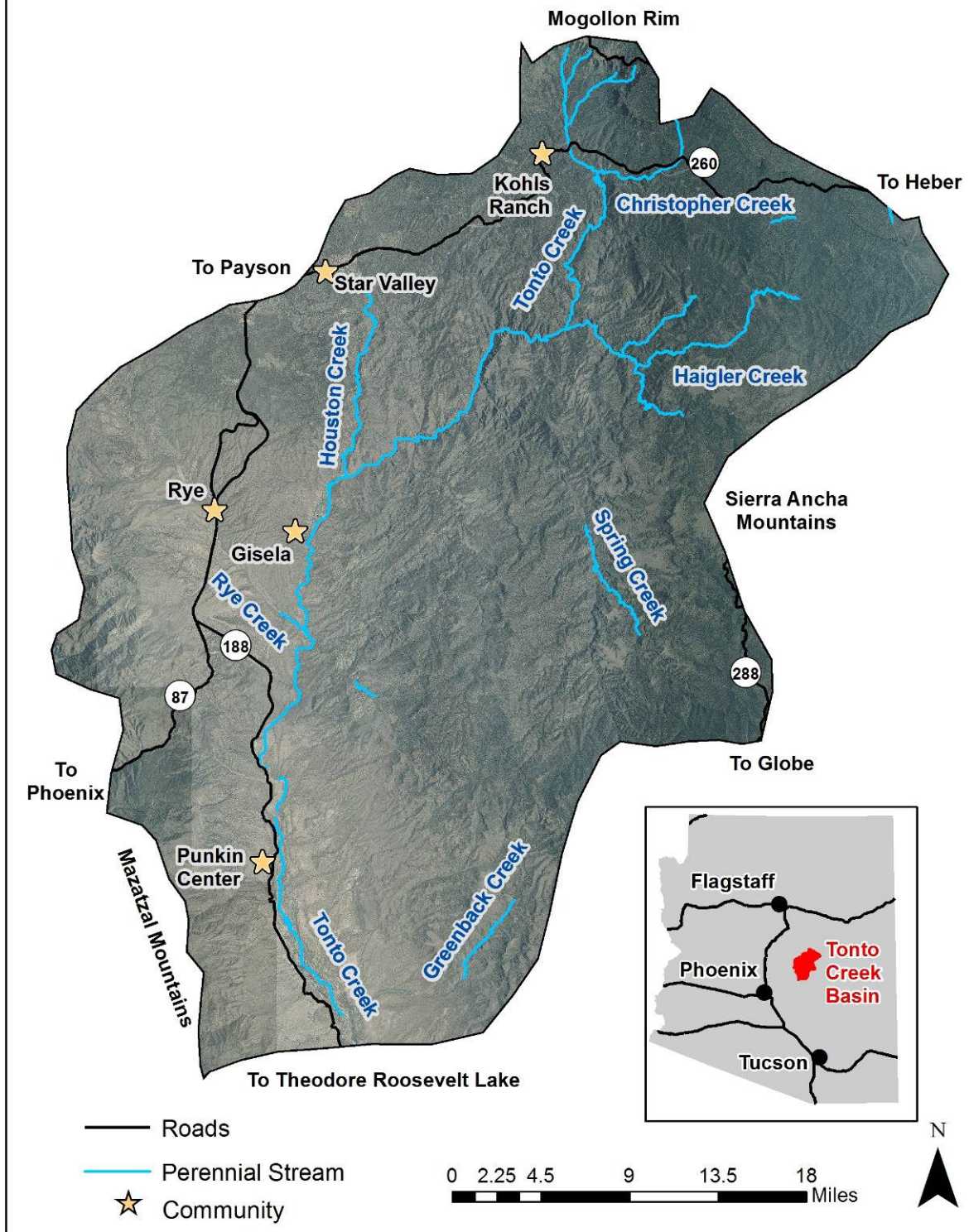
Health-based, Primary Maximum Contaminant Levels (MCLs) were exceeded at eight sites (26 percent). These enforceable standards define the maximum constituent concentration allowed in drinking water provided by a public water system and are based on a lifetime consumption of two liters per day.²⁶ Constituents above Primary MCLs include arsenic (6 sites), gross alpha (2 sites), and 1 site each for nitrate, radium-226+228, and uranium. Aesthetics-based, Secondary MCLs were exceeded at four sites (13 percent). These unenforceable guidelines define the maximum constituent concentration that can be present in drinking water without an unpleasant taste, color, or odor.²⁶ Constituents above Secondary MCLs include fluoride (1 site), manganese (1 site), and total dissolved solids or TDS (3 sites).

Groundwater in the basin typically has calcium or mixed-bicarbonate chemistry and is *slightly-alkaline, fresh, and moderately hard to very hard*, based on pH levels along with TDS and hardness concentrations.^{9, 12} Oxygen and deuterium isotope values at most sites reflected the elevation at which the samples were collected.¹¹

Groundwater constituent concentrations were influenced by geology.^{10, 18} Constituents such as temperature, Specific Conductivity (SC)-field, SC-lab, TDS, sodium, potassium, chloride, strontium, oxygen-18, and deuterium had significantly higher constituent concentrations at sites in unconsolidated sediment than at sites in consolidated rocks (Kruskal-Wallis test, $p \leq 0.05$). Constituents such as temperature, SC-field, SC-lab, TDS, sodium, potassium, chloride, strontium, oxygen-18, and gross alpha generally had significantly greater concentrations in sites located in stream alluvium than in basin fill, and consolidated or sedimentary rock (Kruskal-Wallis test, $p \leq 0.05$).

Groundwater in the Tonto Creek basin is generally suitable for drinking water uses based on results from this ADEQ study and research by the U.S. Geological Survey.^{10, 21} Most samples were of calcium or mixed-bicarbonate chemistry which is characteristic of recently recharged groundwater having low concentrations of TDS, nutrients, and trace elements.²⁰ The limestone aquifer along the Mogollon Rim produces especially pure water. Groundwater from wells tapping the fine-grained facies of the upper part of the basin fill south of Rye however, should be avoided as a drinking water source because of potentially elevated concentrations of arsenic, fluoride, and TDS.^{10, 21}

Map 1 - Tonto Creek Basin



Map 2 - Sample Sites

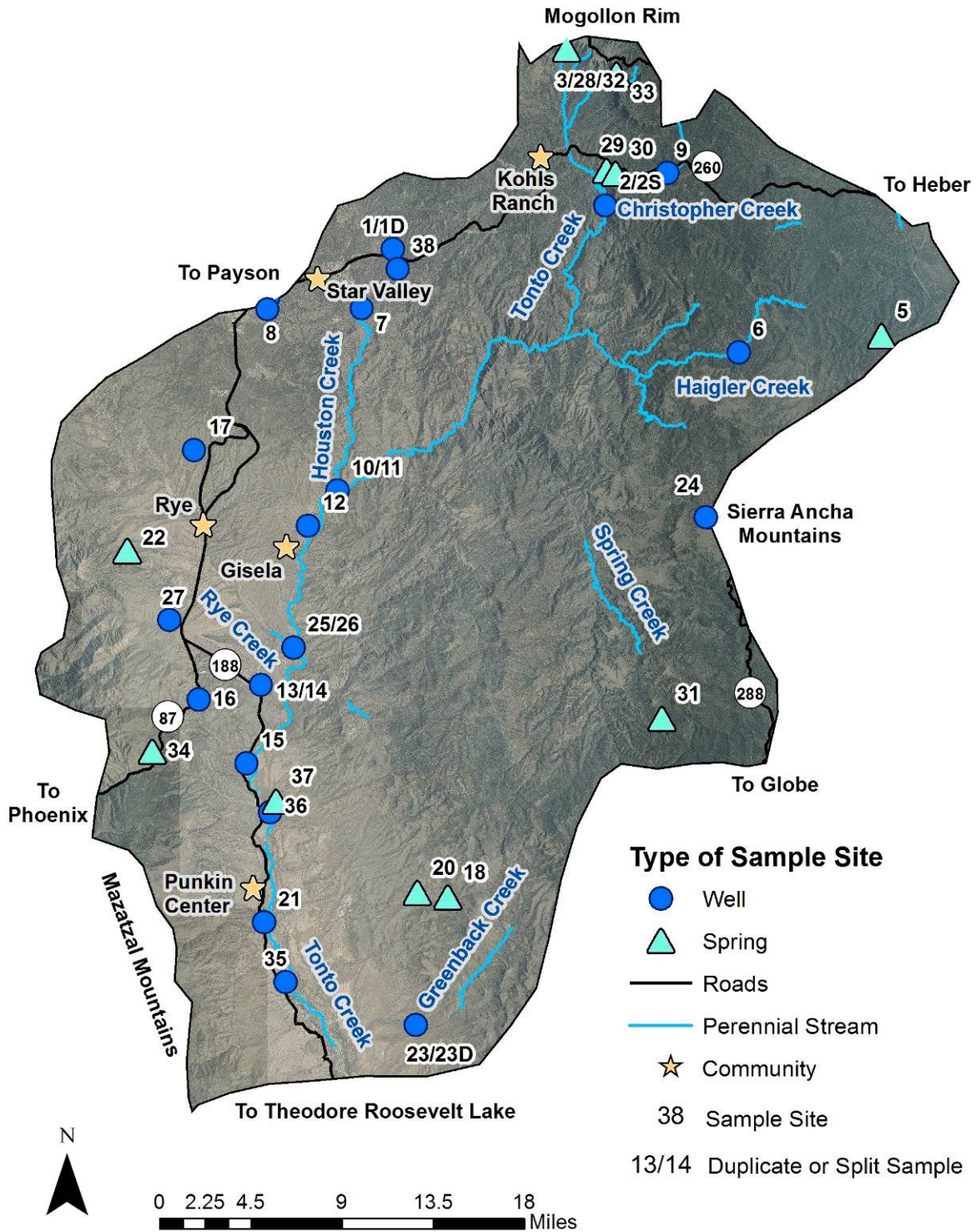




Figure 3 – The sample from Payson Concrete and Materials Well #1 (TON-36) that is used for industrial purposes met all drinking water quality standards.

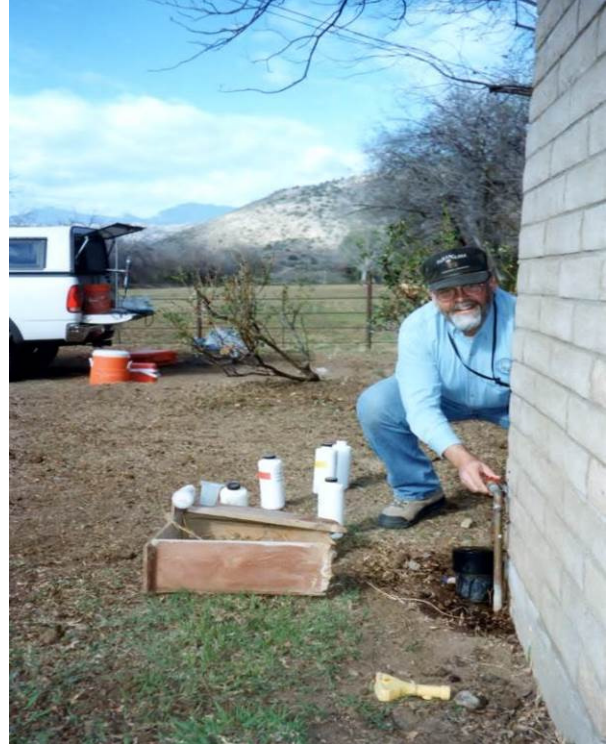


Figure 5 – Former ADEQ employee Joe Harmon collects a sample (TON-10) from a well in Gisela along Tonto Creek that exceeded standards for gross alpha.



Figure 4 – ADEQ's Jade Dickens and Elizabeth Boettcher collect a sample (TON-33) from Horton Spring which discharges an average of 392 gpm just below the Mogollon Rim.⁴



Figure 6 – Former ADEQ employee Susan Determann collects a sample from Tonto Spring just below the Mogollon Rim. Tonto is the largest spring in the basin with an average discharge of 1,291 gpm.⁴

Wells pumping groundwater for domestic, stock, and irrigation purposes were sampled for the study, provided each well met ADEQ requirements. A well was considered suitable for sampling when the following conditions were met: the owner has given permission to sample, a sampling point existed near the wellhead, and the well casing and surface seal appeared to be intact and undamaged.^{1, 5}

For this study, ADEQ personnel sampled 20 wells served by 17 submersible pumps, 2 windmills, and 1 turbine pump. The wells were primarily used for domestic and/or stock use. Eleven springs were also sampled that were primarily used for stock or wildlife watering with one used by a fish hatchery.

Additional information on groundwater sample sites is compiled from the Arizona Department of Water Resources (ADWR) well registry in Appendix A.⁴

Sample Collection

The sample collection methods for this study conformed to the *Quality Assurance Project Plan* (QAPP)¹ and the *Field Manual for Water Quality Sampling*.⁵ While these sources should be consulted as references to specific sampling questions, a brief synopsis of the procedures involved in collecting a groundwater sample is provided.

After obtaining permission from the well owner, the volume of water needed to purge the three bore-hole volumes was calculated from well log and on-site information. Physical parameters—temperature, pH, and specific conductivity—were monitored every five minutes using an YSI multi-parameter instrument.

To assure obtaining fresh water from the aquifer, after three bore volumes had been pumped and physical parameter measurements had stabilized within 10 percent, a sample representative of the aquifer was collected from a point as close to the wellhead as possible. In certain instances, it was not possible to purge three bore volumes. In these cases, at least one bore volume was evacuated and the physical parameters had stabilized within 10 percent.

Sample bottles were filled in the following order:

1. Radon
2. VOCs
3. Inorganics
4. Radionuclide
5. Isotopes

Radon is a naturally occurring, intermediate breakdown from the radioactive decay of uranium-238 to lead-206. These samples were collected in two unpreserved, 40 milliliter (ml) clear glass vials. Radon samples were filled to minimize volatilization and sealed so that no headspace remained.^{5, 22}

VOC samples were collected in two, 40-ml amber glass vials which contained 10 drops of 1:1 hydrochloric (HCl) acid preservative prepared by the laboratory. Before sealing the vials with Teflon caps, pH test strips were used to confirm the pH of the sample was below 2 standard units (su); additional HCl acid was added if necessary. VOC samples were also checked to make sure there were no air bubbles in the vials.¹⁹

The inorganic constituents were collected in three, one-liter polyethylene bottles. Samples to be analyzed for dissolved metals were delivered to the laboratory unfiltered and unpreserved where they were subsequently filtered into bottles using a positive pressure filtering apparatus with a 0.45 micron (µm) pore size groundwater capsule filter and preserved with 5 ml nitric acid (70 percent). Samples to be analyzed for nutrients were preserved with 2 ml sulfuric acid (95.5 percent). Samples to be analyzed for other parameters were unpreserved.^{5, 19, 22}

Radiochemistry samples were collected in two collapsible four-liter plastic containers and preserved with 5 ml nitric acid to reduce the pH below 2.5 su.⁵ Oxygen and hydrogen isotope samples were collected in a 250 ml polyethylene bottle with no preservative.^{5, 25}

All samples were kept at 4°C with ice in an insulated cooler, with the exception of the oxygen and hydrogen isotope samples.^{5, 19, 22, 25} Chain of custody procedures were followed in sample handling. Samples for this study were collected during eight field trips conducted between 2002 and 2012.

Laboratory Methods

All VOC samples and the inorganic analyses for the first 22 inorganic samples, except two split samples, were conducted by the Arizona Department of Health Services (ADHS) Laboratory in Phoenix, Arizona. The inorganic analyses for the last nine inorganic samples plus three split samples (TON-3S, TON-14, and TON-24S) were conducted by Test America Laboratory in Phoenix, Arizona. A complete listing of inorganic parameters, including laboratory method and Minimum Reporting Limit (MRL) for each

Table 1. Laboratory Water Methods and Minimum Reporting Levels Used in the Study-Continued

| Constituent | Instrumentation | ADHS / Test America Water Method | ADHS / Test America Minimum Reporting Level |
|-----------------------|------------------------------|-------------------------------------|------------------------------------------------|
| Trace Elements | | | |
| Aluminum | ICP-AES | EPA 200.7 | 0.5 / 0.2 |
| Antimony | Graphite Furnace AA | EPA 200.8 | 0.005 / 0.003 |
| Arsenic | Graphite Furnace AA | EPA 200.9 / EPA 200.8 | 0.005 / 0.001 |
| Barium | ICP-AES | EPA 200.8 / EPA 200.7 | 0.005 to 0.1 / 0.01 |
| Beryllium | Graphite Furnace AA | EPA 200.9 / EPA 200.8 | 0.0005 / 0.001 |
| Boron | ICP-AES | EPA 200.7 | 0.1 / 0.2 |
| Cadmium | Graphite Furnace AA | EPA 200.8 | 0.0005 / 0.001 |
| Chromium | Graphite Furnace AA | EPA 200.8 / EPA 200.7 | 0.01 / 0.01 |
| Copper | Graphite Furnace AA | EPA 200.8 / EPA 200.7 | 0.01 / 0.01 |
| Fluoride | Ion Selective Electrode | SM 4500 F-C | 0.1 / 0.4 |
| Iron | ICP-AES | EPA 200.7 | 0.1 / 0.05 |
| Lead | Graphite Furnace AA | EPA 200.8 | 0.005 / 0.001 |
| Manganese | ICP-AES | EPA 200.7 | 0.05 / 0.01 |
| Mercury | Cold Vapor AA | SM 3112 B / EPA 245.1 | 0.0002 |
| Nickel | ICP-AES | EPA 200.7 | 0.1 / 0.01 |
| Selenium | Graphite Furnace AA | EPA 200.9 / EPA 200.8 | 0.005 / 0.002 |
| Silver | Graphite Furnace AA | EPA 200.9 / EPA 200.7 | 0.001 / 0.01 |
| Strontium | ICP-AES | EPA 200.7 | 0.1 / 0.1 |
| Thallium | Graphite Furnace AA | EPA 200.9 / EPA 200.8 | 0.002 / 0.001 |
| Zinc | ICP-AES | EPA 200.7 | 0.05 |
| Radionuclides | | | |
| Radon | Liquid scintillation counter | EPA 913.1 | varies |

All units are mg/L Source ^{19, 22}

ntu in the de-ionized water supplied by the ADHS laboratory, and levels increase with time due to storage in ADEQ carboys.¹⁹

For SC, the equipment blank had a value of 1.8 micro-siemens per cm (uS/cm) which was less than 1 percent of the SC mean concentration for the study and was not considered to be significantly affecting the sample results. The SC detections may have occurred when water passing through a de-ionizing exchange unit normally has an SC value of at least 1 uS/cm. Carbon dioxide from the air can also dissolve in de-ionized water with the resulting bicarbonate and hydrogen ions imparting the observed conductivity.¹⁹

The four VOC travel blanks revealed no contamination issues with any of the 34 compounds.

Duplicate Samples – Duplicate samples are identical sets of samples collected from the same source at the same time and submitted to the same laboratory. Data from duplicate samples provide a measure of variability from the combined effects of field and laboratory procedures.⁵ Duplicate samples were collected from sampling sites that were believed to have elevated or unique constituent concentrations as judged by SC-field and pH-field values.

Four duplicate samples were collected and submitted to the ADHS laboratory for this study. Analytical results indicate that of the 40 constituents examined, 20 had concentrations above the MRL. The duplicate samples had an excellent correlation as the maximum variation between constituents was less than 5 percent except for total phosphorus (9 percent), TKN (10 percent), and turbidity (32 percent) (Table 3).

Split Samples – Split samples are identical sets of samples collected from the same source at the same time that are submitted to two different laboratories to check for laboratory differences.⁵ Three inorganic split samples were collected and distributed between the ADHS and Test America labs. The analytical results were evaluated by examining the variability in constituent concentrations in terms of absolute levels and as the percent difference.

Analytical results indicate that of the 36 constituents examined, 20 had concentrations above MRLs for both ADHS and Test America laboratories (Table 3). The maximum variation between constituents was below 5 percent except for zinc (10 percent), chloride (15 percent), potassium (21 percent), turbidity (28 percent), copper (90 percent), and TKN (95 percent) (Table 4).

Split samples were also evaluated using the non-parametric Sign test to determine if there were any significant differences between ADHS laboratory and Test America laboratory analytical results.²⁸ There were no significant differences in constituent concentrations between the labs (Sign test, $p \leq 0.05$).

Based on the results of blank, duplicate, and split samples collected for this study, no significant QA/QC problems were apparent with the study.

Data Validation

The analytical work for this study was subjected to four QA/QC correlations and considered valid based on the following results.¹⁵

Cation/Anion Balances – In theory, water samples exhibit electrical neutrality. Therefore, the sum of milliequivalents per liter (meq/L) of cations should equal the sum of meq/L of anions. However, this neutrality rarely occurs due to unavoidable variation inherent in all water quality analyses. Still, if the cation/anion balance is found to be within acceptable limits, it can be assumed there are no gross errors in concentrations reported for major ions.¹⁵

Overall, cation/anion meq/L balances of Tonto Creek basin samples were significantly correlated (regression analysis, $p \leq 0.01$). Of the 31 samples, all were within +/-5 percent and 25 samples were within +/- 2 percent. Seventeen samples had low cation/high anion sums; 14 samples had high cation/low anion sums.

SC/TDS – The SC-lab and TDS concentrations measured by contract laboratories were significantly correlated as were SC-field and TDS concentrations (regression analysis, $r = 0.98$, $p \leq 0.01$). The TDS concentration in mg/L should be from 0.55 to 0.75 times the SC in $\mu\text{S/cm}$ for groundwater up to several thousand TDS mg/L.¹⁵

Groundwater high in bicarbonate and chloride will have a multiplication factor near the lower end of this range; groundwater high in sulfate may reach or even exceed the higher factor. The relationship of TDS to SC becomes undefined with very high or low concentrations of dissolved solids.¹⁵

SC – The SC measured in the field at the time of sampling was significantly correlated with the SC measured by contract laboratories (regression analysis, $r = 0.99$, $p \leq 0.01$).

Table 4. Summary Results of Split Samples between ADHS / Test America Labs

| Constituents | Number of Split Sites | Difference in Percent | | Difference in Levels | | Significance |
|---------------------------------------------------------|-----------------------|-----------------------|---------|----------------------|---------|--------------|
| | | Minimum | Maximum | Minimum | Maximum | |
| Physical Parameters and General Mineral Characteristics | | | | | | |
| Alkalinity, total | 3 | 0 % | 3 % | 3 | 10 | ns |
| SC (µS/cm) | 3 | 0 % | 2 % | 0 | 10 | ns |
| Hardness | 3 | 3 % | 4 % | 4 | 20 | ns |
| pH (su) | 3 | 1 % | 5 % | 0.11 | 0.7 | ns |
| TDS | 3 | 1 % | 3 % | 10 | 10 | ns |
| Turbidity (ntu) | 1 | 28 % | 28 % | 1.5 | 1.5 | ns |
| Major Ions | | | | | | |
| Calcium | 3 | 1 % | 3 % | 1 | 1 | ns |
| Magnesium | 3 | 0 % | 2 % | 0 | 0.2 | ns |
| Sodium | 3 | 2 % | 7 % | 1 | 10 | ns |
| Potassium | 3 | 0 % | 10 % | 0 | 1.3 | ns |
| Chloride | 3 | 5 % | 15 % | 0.7 | 8 | ns |
| Sulfate | 3 | 0 % | 4 % | 0 | 1 | ns |
| Nutrients | | | | | | |
| Nitrate as N | 1 | 2 % | 2 % | 0.02 | 0.02 | ns |
| TKN* | 1 | 91 % | 91 % | 2.09 | 2.09 | ns |
| Trace Elements | | | | | | |
| Arsenic | 1 | 4 % | 4 % | 0.005 | 0.005 | ns |
| Barium | 1 | 2 % | 2 % | 0.01 | 0.01 | ns |
| Copper | 1 | 15 % | 15 % | 0.004 | 0.004 | ns |
| Fluoride | 3 | 0 % | 7 % | 0 | 0.4 | ns |
| Lead | 1 | 6 % | 6 % | 0.0009 | 0.0009 | ns |
| Zinc | 2 | 0 % | 6 % | 0 | 0.03 | ns |

ns = No significant ($p \leq 0.05$) difference

All units are mg/L except as noted

* = TKN was detected by Test America in (TON-14) at 0.56 mg/L and not detected in the ADHS split sample (TON-13)

Turbidity was detected by ADHS in (TON-2) at 1.3 ntu and not detected in the Test Am. split sample (TON-2S)

GROUNDWATER SAMPLING RESULTS

Water Quality Standards/Guidelines

The ADEQ ambient groundwater program characterizes regional groundwater quality. An important determination ADEQ makes concerning the collected samples is how the analytical results compare to various drinking water quality standards.

ADEQ used three sets of drinking water standards that reflect the best current scientific and technical judgment available to evaluate the suitability of groundwater in the basin for drinking water use:

- Federal Safe Drinking Water (SDW) Primary Maximum Contaminant Levels (MCLs). These enforceable health-based standards establish the maximum concentration of a constituent allowed in water supplied by public systems.²⁶
- State of Arizona Aquifer Water Quality Standards. These apply to aquifers that are classified for drinking water protected use. All aquifers within Arizona are currently classified and protected for drinking water use. These enforceable State standards are identical to the federal Primary MCLs except for arsenic which is at 0.05 mg/L compared with the federal Primary MCL of 0.01 mg/L.²
- Federal SDW Secondary MCLs. These non-enforceable aesthetics-based guidelines define the maximum concentration of a constituent that can be present without imparting unpleasant taste, color, odor, or other aesthetic effects on the water.²⁶

Health-based drinking water quality standards (such as Primary MCLs) are based on the lifetime consumption (70 years) of two liters of water per day and, as such, are chronic not acute standards.²⁶ Exceedances of specific constituents for each groundwater site is found in Appendix B.

Overall Results – Of the 31 sites sampled in the Tonto Basin study, 22 sites met all health-based and aesthetics-based, water quality standards (excluding the proposed radon standard discussed below).

Of the 31 sites sampled in the Tonto Basin study, health-based water quality standards were exceeded at 8 sites (26 percent). Constituents above Primary MCLs include arsenic (6 sites), gross alpha (2 sites), and 1 site each for nitrate, radium-226+228, and uranium.

Inorganic Constituent Results - Of the 31 sites sampled for the full suite of inorganic constituents (excluding radionuclide sample results) in the Tonto Creek study, 23 sites (74 percent) met all health-based and aesthetics-based, water quality standards.

Health-based Primary MCL water quality standards and State aquifer water quality standards were exceeded at 6 sites (19 percent) of the 31 sites (Map 3; Table 5). Constituents above Primary MCLs include arsenic (6 sites) and nitrate (1 site). Potential impacts of these Primary MCL exceedances are given in Table 5.

Aesthetics-based Secondary MCL water quality guidelines were exceeded at 4 of 31 sites (13 percent; Map 3; Table 6). Constituents above Secondary MCLs include fluoride (1 site), manganese (1 site), and TDS (3 sites). Potential impacts of these Secondary MCL exceedances are given in Table 6.

Radon Results - Of the five sites sampled for radon, none exceeded the proposed 4,000 picocuries per liter (pCi/L) standard that would apply if Arizona establishes an enhanced multimedia program to address the health risks from radon in indoor air. All five sites exceeded the proposed 300 pCi/L standard (Table 4) that would apply if Arizona doesn't develop a multimedia program.²⁶

Analytical Results

Analytical inorganic and radiochemistry results of the Tonto Basin sample sites are summarized (Table 7) using the following indices: MRLs, number of sample sites over the MRL, upper and lower 95 percent confidence intervals (CI_{95%}), median, and mean. Confidence intervals are a statistical tool which indicates that 95 percent of a constituent's population lies within the stated confidence interval.²⁸ Specific constituent information for each sampled groundwater site is in Appendix B.

Table 5. Sampled Sites Exceeding Health-based Water Quality Standards or Primary MCLs

| Constituent | Primary MCL | Number of Sites Exceeding Primary MCL | Highest Concentration | Potential Health Effects of MCL Exceedances * |
|------------------------------------|-------------|---------------------------------------|-----------------------|-----------------------------------------------|
| Nutrients | | | | |
| Nitrite (NO ₂ -N) | 1.0 | 0 | - | - |
| Nitrate (NO ₃ -N) | 10.0 | 1 | 28.5 | methemoglobinemia |
| Trace Elements | | | | |
| Antimony (Sb) | 0.006 | 0 | - | - |
| Arsenic (As) | 0.01 | 6 | 0.20 | dermal and nervous system toxicity |
| Arsenic (As) | 0.05 | 0 | - | - |
| Barium (Ba) | 2.0 | 0 | - | - |
| Beryllium (Be) | 0.004 | 0 | - | - |
| Cadmium (Cd)** | 0.005 | 0 | - | - |
| Chromium (Cr) | 0.1 | 0 | - | - |
| Copper (Cu) | 1.3 | 0 | - | - |
| Fluoride (F) | 4.0 | 0 | - | - |
| Lead (Pb) | 0.015 | 0 | - | - |
| Mercury (Hg) | 0.002 | 0 | - | - |
| Nickel (Ni) | 0.1 | 0 | - | - |
| Selenium (Se) | 0.05 | 0 | - | - |
| Thallium (Tl)** | 0.002 | 0 | - | - |
| Radiochemistry Constituents | | | | |
| Gross Alpha | 15 | 2 | 210 | cancer |
| Ra-226+Ra-228 | 5 | 1 | 10 | - |
| Radon *** | 300 | 5 | 906 | cancer |
| Radon *** | 4,000 | 0 | - | - |
| Uranium | 30 | 1 | 220 | cancer and kidney toxicity |

All units are mg/L except gross alpha, radium-226+228 and radon (pCi/L), and uranium (ug/L).

* Health-based drinking water quality standards are based on a lifetime consumption of two liters of water per day over a 70-year life span.²⁶

** One sample exceeded this Primary MCL was likely from contamination.

*** Proposed EPA Safe Drinking Water Act standards for radon in drinking water.²⁶

Table 7. Summary Statistics for Groundwater Quality Data

| Constituent | Minimum Reporting Limit (MRL)* | # of Samples / Samples Over MRL | Median | Lower 95% Confidence Interval | Mean | Upper 95% Confidence Interval |
|----------------------------------------|--------------------------------|---------------------------------|-------------------------|-------------------------------|------|-------------------------------|
| Physical Parameters | | | | | | |
| Temperature (°C) | 0.1 | 31 / 31 | 17.2 | 15.1 | 17.1 | 19.0 |
| pH-field (su) | 0.01 | 31 / 31 | 7.45 | 7.31 | 7.47 | 7.62 |
| pH-lab (su) | 0.01 | 31 / 31 | 7.50 | 7.37 | 7.51 | 7.65 |
| Turbidity (ntu) | 0.01 / 0.20 | 31 / 28 | 0.3 | 0.3 | 1.2 | 2.0 |
| General Mineral Characteristics | | | | | | |
| T. Alkalinity | 2.0 / 6.0 | 31 / 31 | 240 | 206 | 244 | 282 |
| Phenol. Alk. | 2.0 / 6.0 | 31 / 0 | > 50% of data below MRL | | | |
| SC-field (µS/cm) | N/A | 31 / 31 | 536 | 470 | 576 | 682 |
| SC-lab (µS/cm) | N/A / 2.0 | 31 / 31 | 560 | 596 | 576 | 703 |
| Hardness-lab | 10 / 6 | 31 / 31 | 250 | 201 | 242 | 285 |
| TDS | 10 / 20 | 31 / 31 | 330 | 284 | 349 | 415 |
| Major Ions | | | | | | |
| Calcium | 5 / 2 | 31 / 31 | 65 | 54 | 65 | 76 |
| Magnesium | 1.0 / 0.25 | 31 / 31 | 17 | 15 | 20 | 24 |
| Sodium | 5 / 2 | 31 / 31 | 17 | 15 | 35 | 55 |
| Potassium | 0.5 / 2.0 | 31 / 26 | 2.1 | 1.9 | 2.6 | 3.2 |
| Bicarbonate | 2.0 / 6.0 | 31 / 31 | 290 | 252 | 298 | 344 |
| Carbonate | 2.0 / 6.0 | 31 / 0 | > 50% of data below MRL | | | |
| Chloride | 1 / 20 | 31 / 30 | 12 | 17 | 29 | 41 |
| Sulfate | 10 / 20 | 31 / 30 | 13 | 10 | 24 | 37 |
| Nutrients | | | | | | |
| Nitrate (as N) | 0.02 / 0.20 | 31 / 20 | 0.1 | -0.7 | 1.2 | 3.0 |
| Nitrite (as N) | 0.02 / 0.20 | 31 / 0 | > 50% of data below MRL | | | |
| TKN | 0.05 / 1.0 | 31 / 11 | > 50% of data below MRL | | | |
| Ammonia | 0.02 / 0.05 | 31 / 3 | > 50% of data below MRL | | | |
| T. Phosphorus | 0.02 / 0.10 | 31 / 11 | > 50% of data below MRL | | | |

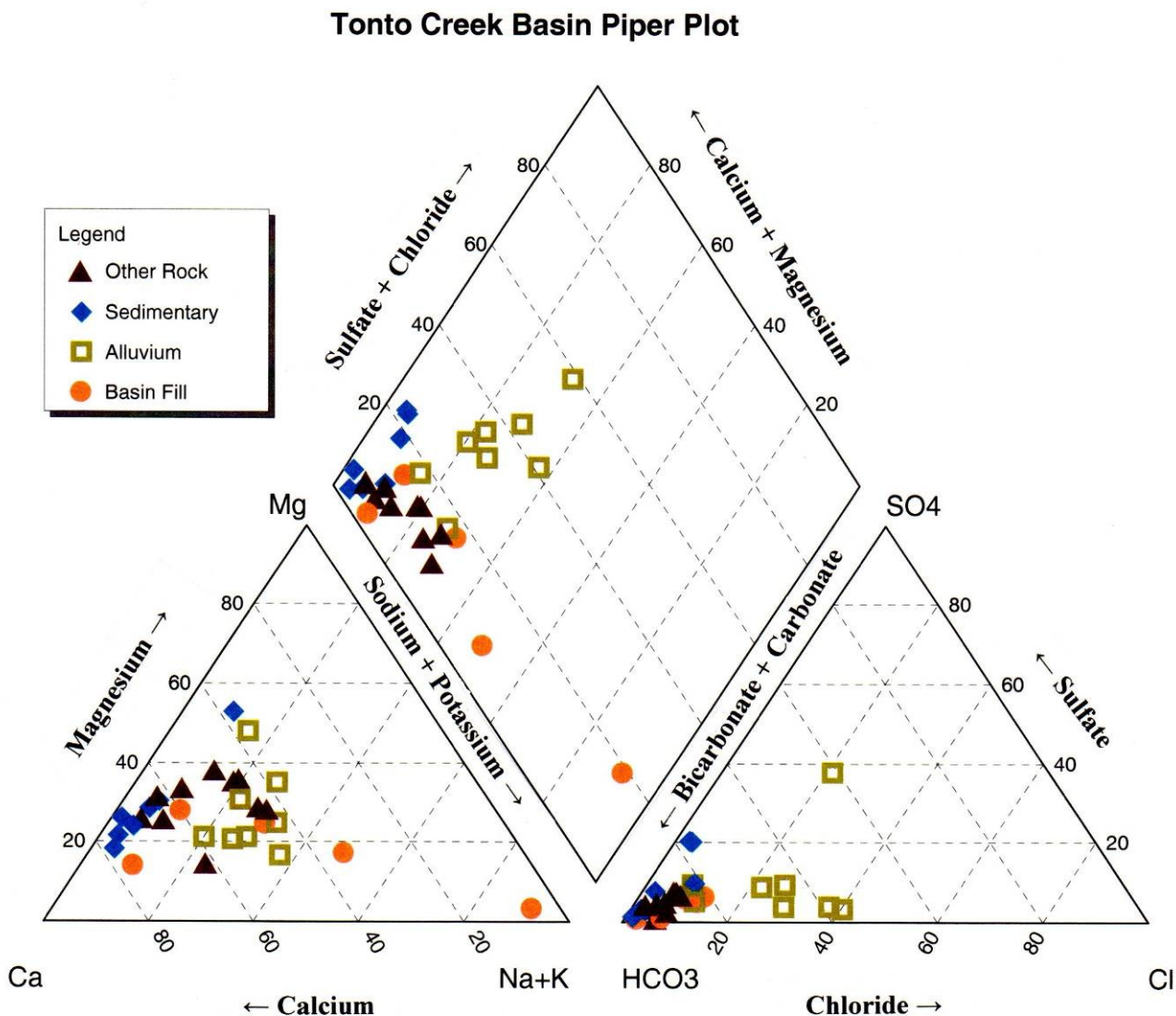
GROUNDWATER COMPOSITION

General Summary

The water chemistry of the 31 sample sites in the Tonto Basin (in decreasing frequency) include calcium-bicarbonate (16 sites), mixed-bicarbonate (12 sites), sodium-bicarbonate, magnesium-bicarbonate, and mixed-mixed (1 site apiece) (Diagram 2 – middle figure) (Map 4).

The dominant cation was calcium at 16 sites and sodium and magnesium at 1 site apiece. At 13 sites the composition was mixed as there was no dominant cation (Diagram 2 – left figure).

The dominant anion was bicarbonate at 30 sites. The composition was mixed as there was no dominant anion at one site (Diagram 2 – right figure).



At 25 sites, levels of pH-field were *slightly alkaline* (above 7 su) and 1 site was above 8 su. At 6 sites, pH-field levels were *slightly acidic* (below 7 su)¹³

TDS concentrations were considered *fresh* (below 999 mg/L) at all 31 sites (Map 5).¹³

Hardness concentrations were *soft* (below 75 mg/L) at 1 site, *moderately hard* (75 – 150 mg/L) at 6 sites, *hard* (150 – 300 mg/L) at 17 sites, and *very hard* (300 - 600 mg/L) at 7 sites (Map 6).⁹

Nitrate (as nitrogen) concentrations at most sites may have been influenced by human activities. Nitrate concentrations were divided into natural background (19 sites at < 0.2 mg/L), may or may not indicate human influence (11 sites at 0.2 – 3.0 mg/L), may result from human activities (0 sites at 3.0 – 10 mg/L), and probably result from human activities (1 site > 10 mg/L).¹⁶

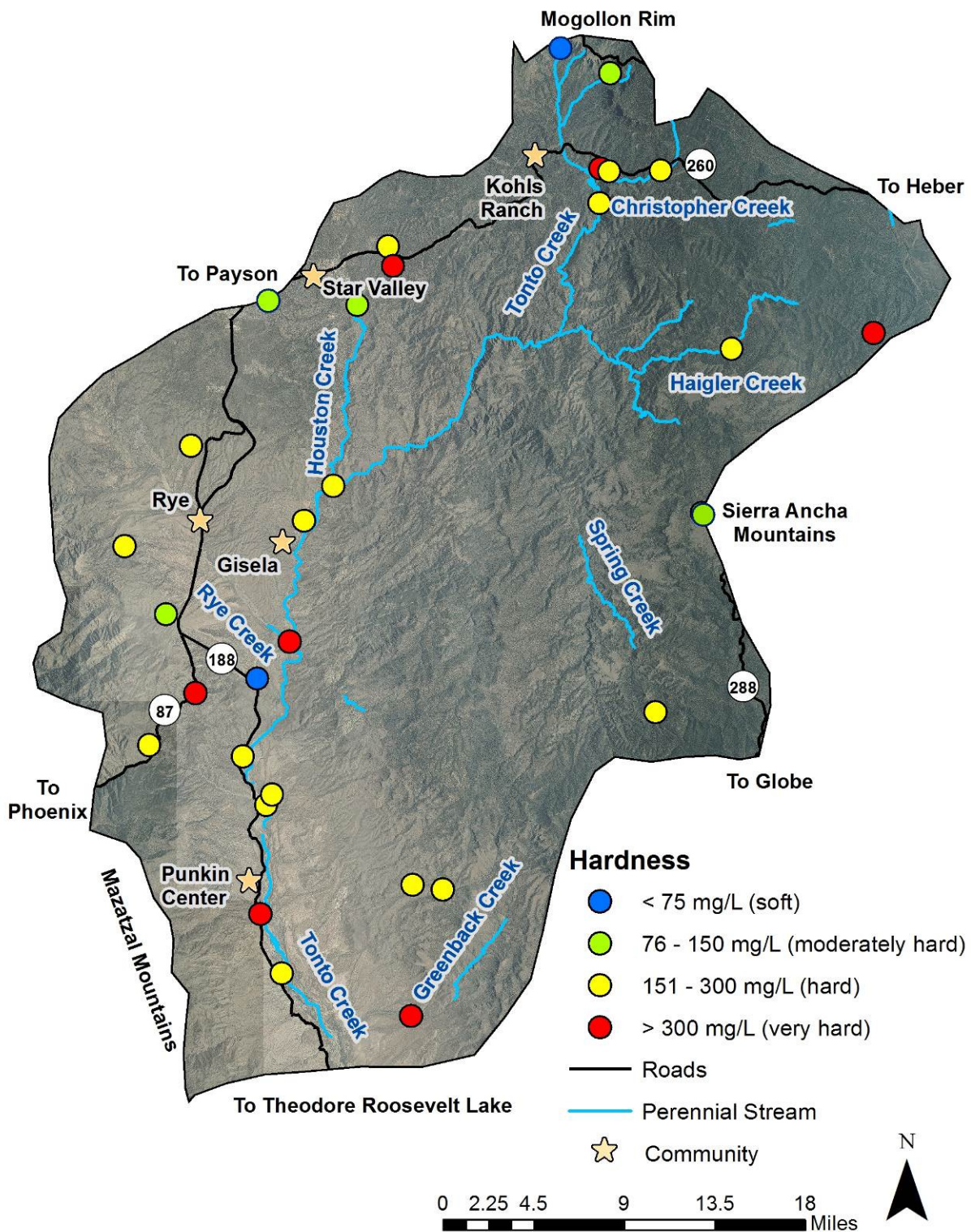
Most trace elements such as aluminum, antimony, beryllium, boron, cadmium, chromium, iron, lead, manganese, mercury, nickel, selenium, silver, and thallium were rarely – if ever - detected. Only arsenic, barium, copper, fluoride, strontium, and zinc were detected at more than 25 percent of the sites.

The groundwater at each sample site was assessed as to its suitability for irrigation use based on salinity and sodium hazards. Excessive levels of sodium are known to cause physical deterioration of the soil and vegetation. Irrigation water may be classified using SC and the Sodium Adsorption Ratio (SAR) in conjunction with one another.²⁸ Groundwater sites in the Tonto Basin display a narrow range of irrigation water classifications. Samples predominantly had a “low” sodium hazard and a “medium” salinity hazard (Table 8).

Table 8. Sodium and Salinity Hazards for Sampled Sites

| Hazard | Total Sites | Low | Medium | High | Very High |
|-------------------------------|--------------------|------------|---------------|-------------|------------------|
| Sodium Hazard | | | | | |
| Sodium Adsorption Ratio (SAR) | | 0 - 10 | 10- 18 | 18 - 26 | > 26 |
| Sample Sites | 31 | 30 | 0 | 1 | 0 |
| Salinity Hazard | | | | | |
| Specific Conductivity (µS/cm) | | 100–250 | 250 – 750 | 750-2250 | >2250 |
| Sample Sites | 31 | 4 | 20 | 7 | 0 |

Map 6 - Hardness



ong Groundwater Quality Constituent Concentrations

| pH-f | pH-lab | SC-f | SC-lab | TDS | Hard | Ca | Mg | Na | K | Bic | Cl | SO ₄ | NO ₃ | F | Gross Alpha | Gross Beta |
|---------------------------------|--------|------|--------|-----|------|----|----|----|----|-----|----|-----------------|-----------------|----|-------------|------------|
| Physical Parameters | | | | | | | | | | | | | | | | |
| | ** | ** | ** | | | | | ** | ** | ** | ** | ** | | ** | ** | ** |
| | | | | | | | | | | | | ++ | | | | |
| | | | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | | * | * | ** |
| | | | | ** | ** | ** | ** | ** | ** | ** | ** | ** | | * | * | ** |
| General Mineral Characteristics | | | | | | | | | | | | | | | | |
| | | | | | ** | ** | ** | ** | ** | ** | ** | ** | | * | * | ** |
| | | | | | | ** | ** | | | ** | * | ** | * | | | * |
| Major Ions | | | | | | | | | | | | | | | | |
| | | | | | | | ** | | | ** | * | * | * | | | |
| | | | | | | | | | ** | ** | ** | ** | ** | | | ** |
| | | | | | | | | | ** | ** | ** | ** | | ** | ** | ** |
| | | | | | | | | | | ** | ** | ** | | ** | * | ** |
| | | | | | | | | | | | ** | ** | ** | ** | ** | ** |
| | | | | | | | | | | | | ** | ** | | | ** |
| Nutrients | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| Trace Elements | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | * | * |
| Radioactivity | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | ** |

nt relationship between constituent concentrations

ationship at $p \leq 0.05$

ationship at $p \leq 0.01$

ationship at $p \leq 0.05$

ationship at $p \leq 0.01$

Map 7 - Isotope

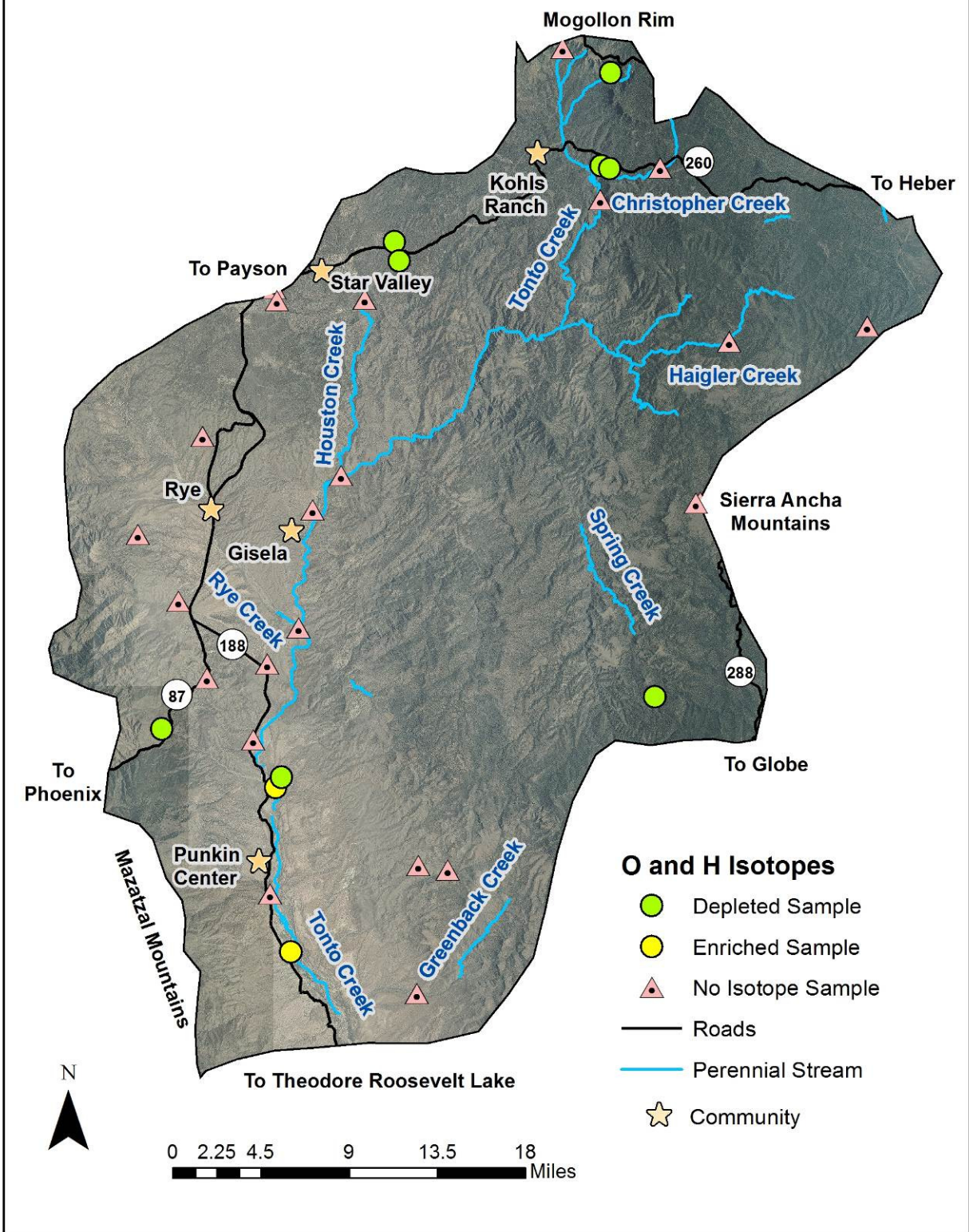


Table 9. Variation in Groundwater Quality Constituent Concentrations between Two Geologic Groups

| Constituent | Sites Sampled | Significance | Significant Differences Between Two Geologic Groups |
|---------------------|---------------|--------------|-----------------------------------------------------|
| Temperature - field | 31 | ** | Unconsolidated > Consolidated |
| pH – field | 31 | ns | - |
| pH – lab | 31 | ns | - |
| SC - field | 31 | ** | Unconsolidated > Consolidated |
| SC - lab | 31 | ** | Unconsolidated > Consolidated |
| TDS | 31 | ** | Unconsolidated > Consolidated |
| Turbidity | 31 | ns | - |
| Hardness | 31 | ns | - |
| Calcium | 31 | ns | - |
| Magnesium | 31 | ns | - |
| Sodium | 31 | ** | Unconsolidated > Consolidated |
| Potassium | 31 | ** | Unconsolidated > Consolidated |
| Bicarbonate | 31 | ns | - |
| Chloride | 31 | ** | Unconsolidated > Consolidated |
| Sulfate | 31 | ns | - |
| Nitrate (as N) | 31 | ns | - |
| Barium | 31 | ns | - |
| Fluoride | 31 | ns | - |
| Strontium | 10 | * | Unconsolidated > Consolidated |
| Gross alpha | 19 | ns | - |
| Gross beta | 19 | ns | - |
| Radon | 5 | ns | - |
| Oxygen | 10 | ** | Unconsolidated > Consolidated |
| Deuterium | 10 | ** | Unconsolidated > Consolidated |

ns = not significant

* = significant at $p \leq 0.05$ or 95% confidence level** = significant at $p \leq 0.01$ or 99% confidence level

Between Four Geologic Groups – Twenty-four groundwater quality constituents were compared between four geologic types: alluvium (nine sites), basin fill (five sites), consolidated sedimentary rocks (seven sites), and igneous and metamorphic (or “other rock”) rocks (ten sites).^{4, 10, 18}

Significant concentration differences were found with seven constituents: temperature, SC-field, SC-lab,

TDS, sodium (Diagram 7), potassium, chloride (Diagram 8 and Map 8), strontium, oxygen-18, and gross alpha (Kruskal-Wallis test, $p \leq 0.05$).

Complete statistical results are in Table 11 and 95 percent confidence intervals for significantly different groups based on recharge groups are in Table 12.

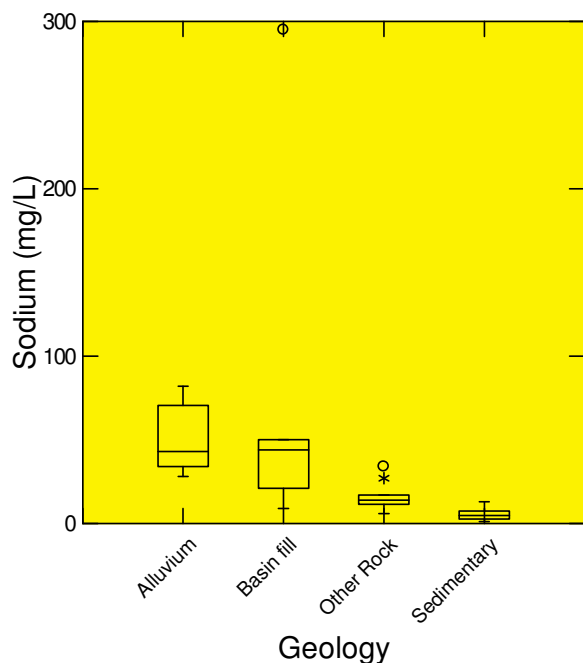


Diagram 7 – Samples collected from sites in basin fill sediments have significantly higher sodium concentrations than sample sites collected from sedimentary or other consolidated rock. Samples collected from sites in alluvium did not have significant differences in sodium concentrations (Kruskal-Wallis, $p \leq 0.05$). Low concentrations of sodium typically occur in recharge areas and increase downgradient as the result of silicate weathering and halite dissolution along with ion exchange.²⁰

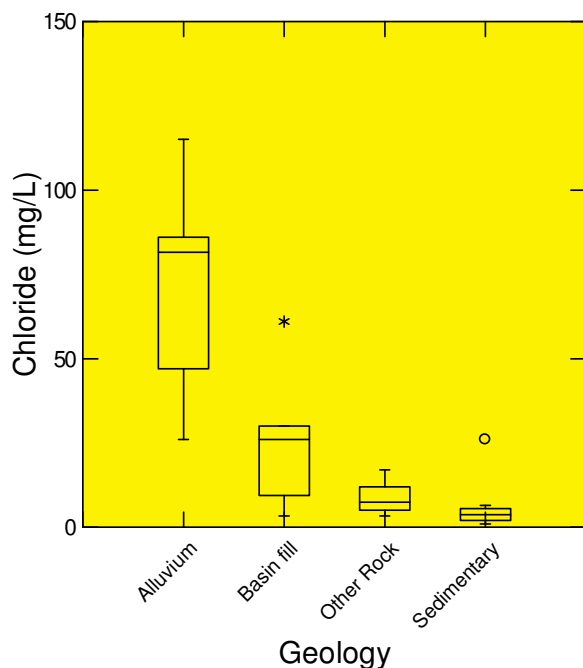


Diagram 8 – Samples collected from sites in stream alluvium have significantly higher chloride concentrations than sample sites collected from basin-fill sediments, sedimentary or other consolidated rock (Kruskal-Wallis, $p \leq 0.05$). Downgradient areas often evolve into sodium-chloride chemistry as TDS concentrations increase.²⁰

Table 12. Summary Statistics for Four Geologic Groups with Significant Constituent Differences

| Constituent | Significance | Alluvium | Basin Fill | Other Rock | Sedimentary |
|---------------------|--------------|---------------|------------|---------------|-------------|
| Temperature - field | ** | 18.6 to 25.0 | - | 13.8 to 17.8 | 6.9 to 15.0 |
| pH – field | ns | - | - | - | - |
| pH – lab | ns | - | - | - | - |
| SC - field | ** | 584 to 1002 | - | 326 to 521 | 226 to 631 |
| SC - lab | ** | 603 to 1033 | - | 343 to 538 | 239 to 657 |
| TDS | * | 334 to 616 | - | 205 to 316 | 140 to 384 |
| Turbidity | ns | - | - | - | - |
| Hardness | ns | - | - | - | - |
| Calcium | ns | - | - | - | - |
| Magnesium | ns | - | - | - | - |
| Sodium | ** | - | -64 to 232 | 9 to 22 | 2 to 10 |
| Potassium | ** | - | - | - | - |
| Bicarbonate | ns | - | - | - | - |
| Chloride | ** | 45 to 95 | -2 to 54 | 6 to 12 | -1 to 15 |
| Sulfate | ns | - | - | - | - |
| Nitrate (as N) | ns | - | - | - | - |
| Barium | ns | - | - | - | - |
| Fluoride | ns | - | - | - | - |
| Strontium | * | 0.1 to 1.4 | - | 0.0 to 0.5 | - |
| Gross alpha | * | - | - | - | - |
| Gross beta | ns | - | - | - | - |
| Radon | ns | - | - | - | - |
| Oxygen | * | -11.3 to -6.5 | - | -11.0 to -9.7 | - |
| Deuterium | ns | - | - | - | - |

ns = not significant

* = significant at $p \leq 0.05$ or 95% confidence level

** = significant at $p \leq 0.01$ or 99% confidence level

All units are mg/L except where indicated.

DISCUSSION

Groundwater in the Tonto Creek basin is generally suitable for drinking water uses based on the water quality results from sampling conducted for the ADEQ ambient study. Most samples collected in the basin are of calcium or mixed-bicarbonate chemistry, which is characteristic of recently recharged groundwater.²⁰ These samples have low TDS concentrations. Nutrients and trace elements are usually not detected. When they are detected, they are typically below water quality standards. Some parts of the basin, such as the limestone aquifer along the Mogollon Rim recharged from precipitation on southern edge of the Colorado Plateau produce some of the purist water in Arizona.¹⁰ Major springs discharging from this aquifer, such as Tonto and Horton, have TDS concentrations less than 100 mg/L. The general acceptability of groundwater for drinking water uses is supported by earlier studies conducted by the U.S. Geological Survey.^{10, 21}

Samples from 22 of the 31 sites (71 percent) met all water quality standards.²⁶ Of the remaining nine sample sites, the constituents that most commonly impacted the acceptability of water for drinking purposes was arsenic with lesser occurrences of elevated concentrations of radionuclides and nitrate. These are three of the four constituents that most commonly exceed health-based water quality standards in Arizona.²³

Arsenic exceedances in the Tonto Creek basin all occurred in samples collected from six sites located in unconsolidated sediment (basin fill or stream alluvium) downgradient from Gisela. Arsenic exceedances ranged from just over the 0.01 mg/L limit to a high of 0.0665 mg/L. Not all of the samples collected in the southern portion of Tonto Creek basin however, had arsenic concentrations exceeding water quality standards.

Unlike in some other Arizona basins, these sites did not have elevated pH levels so that reactions with hydroxyl ions do not appear to be the main cause of elevated arsenic concentrations.²⁰ An oxidizing environment and lithology appear to have been important factors in the five Primary MCL exceedances that were narrowly over the 0.01 mg/L standard in the Tonto Creek basin.

Aquifer residence time appears to be an important contribution to the highest arsenic concentration collected from the split sample (TON-13/14) collected from the deepest well (260 feet) sampled in the study that was located near Punkin Center. The

groundwater sodium-bicarbonate chemistry from this well was very dissimilar to all the other samples collected in the basin. The sample was also the only one in the basin that had a fluoride concentration exceeding the 2.0 mg/L aesthetics water quality standard and one of three that exceeded the TDS Secondary MCL of 500 mg/L. Although no isotope sample was collected from the site, the well is likely producing water that has had a long aquifer residence time as evidenced by the unique water chemistry and elevated concentrations of trace elements. Another well that appears to be pumping water from the same formation was sampled in 1979 for the U.S. Geological Survey study. The 207-foot well (A-6-10-10) also exceeded water quality standards for arsenic, fluoride, and TDS.¹⁰ Groundwater from wells such as these tapping the fine-grained facies of the upper part of the basin fill should be avoided as a drinking water source.^{10, 21}

Gross alpha exceeded health-based, water quality standards in radionuclide samples collected from two of 19 sites. Sample sites were located in (TON-2/2S) or near granitic geology (TON-10/11) which is associated with elevated radionuclide concentrations in groundwater.¹⁶ However, other samples (TON-1/1D, TON-38, and TON-7) collected from wells and/or springs in granitic geology from which radionuclide samples were collected did not exceed water quality standards.

Nitrate exceeded health-based, water quality standards (28.5 mg/L) in duplicate samples (TON-25/26) collected from a 175-foot well located at a remote ranch homestead surrounded by Forest Service lands located north of Punkin Center along Tonto Creek. The sample also had the study's highest TDS concentration (825 mg/L) and chloride concentration (115 mg/L). Elevated nitrate concentrations are likely due to discharges from a septic system as both of TDS and chloride are also indicators of septic system discharge.⁶

In the basin, there is a tendency for constituent concentrations to be significantly higher in groundwater sites collected in unconsolidated sediment and especially stream alluvium. These trends however, generally do not impact the acceptability of these sites for use as a drinking water source.

REFERENCES

- ¹ Arizona Department of Environmental Quality, 1991, Quality Assurance Project Plan: Arizona Department of Environmental Quality Standards Unit, 209 p.

Appendix A. Data for Sample Sites, Tonto Creek Basin, 2002 – 2012

| Site # | Cadastral / Pump Type | Latitude - Longitude | ADWR # | ADEQ # | Site Name | Samples Collected | Well Depth | Water Depth | Geology |
|----------------------------------------------------------------------------------------------------|---------------------------|------------------------------|--------|--------|----------------------|---------------------------|------------|-------------|-------------|
| 1st Field Trip, January 22-24, 2002 – Harmon & Lucci | | | | | | | | | |
| TON-1/1D duplicate | A(11-11)27cba submersible | 34°16'04.940" 111°13'07.019" | 648682 | 59459 | Davis Well | Inorganic Radiochem | 160' | 75' | Other Rock |
| TON-2/2S split | A(11-12)34dda submersible | 34°17'37.290" 111°03'59.880" | 636650 | 59481 | Collins Well | Inorganic, VOCs Radiochem | 210' | 25' | Other Rock |
| TON-3/28/32 | A(12-12)33bac spring | 34°23'09.68" 111°05'42.791" | - | 59476 | Tonto Crk Hatchry Sp | Inorganic | - | - | Sedimentary |
| TON-5 | A(10-14)13bba spring | 34°12'59.290" 111°52'10.272" | - | 59460 | Clay Spring | Inorganic Radiochem | - | - | Sedimentary |
| TON-6 | A(10-13)13aba submersible | 34°12'25.476" 111°58'18.273" | 582238 | 59461 | Nye Well | Inorganic, VOCs Radiochem | 140' | 90' | Other Rock |
| TON-7 | A(10-11)05ddc submersible | 34°13'59.743" 111°14'26.523" | 539489 | 59462 | Korner Well | Inorganic Radiochem | 200' | 30' | Other Rock |
| TON-8 | A(10-10)02bbc submersible | 34°14'22.923" 111°18'26.053" | 600871 | 12292 | FS Ranger Well | Inorganic Radiochem | - | - | Other Rock |
| TON-9 | A(11-13)30bad submersible | 34°18'47.121" 111°01'21.973" | 542599 | 59463 | Cheney Well | Inorganic Radiochem | 120' | 20' | Sedimentary |
| 2nd Field Trip, March 18-20, 2002 – Towne & Harmon (Equipment Blank, TON-19) | | | | | | | | | |
| TON-10/11 duplicate | A(9-11)18dca submersible | 34°00'06.455" 111°21'26.534" | 623457 | 59754 | Bassett Well | Inorganic Radiochem | 50' | - | Alluvium |
| TON-12 | A(9-10)24cda turbine | 34°06'16.124" 111°16'45.025" | 513641 | 59596 | Siebert Well | Inorganic, Radon VOCs | 45' | 25' | Alluvium |
| TON-13/14 split | A(8-10)27adb submersible | 34°00'37.636" 111°18'45.445" | 576386 | 59597 | Whately Well | Inorganic Radiochem | 260' | 4' | Basin Fill |
| TON-15 | A(7-10)10dbb submersible | 33°57'50.060" 111°19'22.770" | 505978 | 59598 | Mitchell Well | Inorganic, Radon VOCs | 95' | 75' | Alluvium |
| TON-16 | A(8-10)29cdd windmill | 34°00'06.455" 111°21'26.534" | 601017 | 11864 | Gold Creek Windmill | Inorganic Radiochem | - | - | Basin Fill |
| TON-17 | A(9-10)05cbc windmill | 34°08'57.406" 111°21'37.281" | - | 59599 | Harris Windmill | Inorganic Radiochem | 130' | - | Basin Fill |
| TON-18 | A(6-11)12aad spring | 33°53'03.889" 111°10'46.380" | - | 59600 | Oak Ranch Spring | Inorganic | - | - | Other Rock |
| TON-20 | A(6-11)02cdb spring | 33°53'13.246" 111°12'04.353" | - | 59601 | Walnut Spring | Inorganic VOC | - | - | Other Rock |
| TON-21 | A(6-10)14bba submersible | 33°52'10.874" 111°18'38.728" | 500197 | 11576 | Cline Well | Inorganic Radon | 40' | 15' | Alluvium |
| TON-22 | A(9-9)26cca spring | 34°05'22.415" 111°24'30.309" | - | 59602 | Boone Moore Spr | Inorganic, Radiochem | - | - | Basin Fill |
| 3rd Field Trip, April 9-10, 2002 – Harmon & Lucci | | | | | | | | | |
| TON-23/23D duplicate | A(5-11)02bac submersible | 33°48'31.221" 111°12'07.920" | 630180 | 59700 | Speer Well | Inorganic, Radiochem VOCs | 50' | 18' | Alluvium |
| TON-24/24S split | A(9-13)23bcc submersible | 34°06'33.144" 110°59'34.852" | 648977 | 59701 | Seeley Well | Inorganic, Radiochem VOCs | 162' | 40' | Other Rock |
| 4th Field Trip, May 3, 2002 – Towne & Harmon | | | | | | | | | |
| TON-25/26 duplicate | A(8-10)13cdb submersible | 34°01'57.197" 111°17'23.091" | 622906 | 59811 | Neal Well | Inorganic, Radiochem | 175' | 25' | Alluvium |
| TON-27 | A(8-10)07cbd submersible | 34°02'54.141" 111°22'41.756" | - | 11856 | Haught Windmill | Inorganic, Radiochem VOCs | - | - | Basin Fill |

Appendix B. Groundwater Quality Data, Tonto Creek Basin, 2002-2012---Continued

| Site # | MCL Exceedances | Temp (°C) | pH-field (su) | pH-lab (su) | SC-field (µS/cm) | SC-lab (µS/cm) | TDS (mg/L) | Hard (mg/L) | Hard - cal (mg/L) | Turb (ntu) |
|-------------|---------------------------|-----------|---------------|-------------|------------------|----------------|------------|-------------|-------------------|------------|
| TON-1/1D | - | 12.5 | 7.63 | 7.65 | 434 | 460 | 260 | 220 | 230 | 0.095 |
| TON-2/2S | Gross alpha Ra-226+228, U | 13.7 | 7.53 | 7.59 | 502 | 530 | 285 | 255 | 250 | 1.3 |
| TON-3/28/32 | - | 9.6 | 7.6 | 7.2 | 146 | 160 | 82 | 76 | 75 | 1.2 |
| TON-5 | - | 1.7 | 7.69 | 7.8 | 634 | 670 | 370 | 380 | 350 | 0.40 |
| TON-6 | - | 14.4 | 6.98 | 7.5 | 471 | 500 | 260 | 290 | 250 | 0.22 |
| TON-7 | - | 13.8 | 6.95 | 6.7 | 204 | 220 | 150 | 78 | 77 | 0.34 |
| TON-8 | - | 13.4 | 6.80 | 6.5 | 225 | 240 | 160 | 87 | 85 | 0.34 |
| TON-9 | Mn | 11.3 | 6.94 | 7.2 | 536 | 560 | 320 | 280 | 280 | 12 |
| TON-10/11 | Gross alpha | 21.1 | 7.27 | 7.5 | 808 | 817.5 | 455 | 240 | 240 | 5.0 |
| TON-12 | As | 18.6 | 6.97 | 7.3 | 826 | 860 | 473 | 260 | 270 | 0.33 |
| TON-13/14 | As, F, TDS | 22.8 | 7.60 | 7.95 | 1294 | 1300 | 795 | 63 | 62 | 0.06 |
| TON-15 | As | 17.8 | 7.54 | 7.5 | 618 | 640 | 330 | 220 | 220 | 0.04 |
| TON-16 | - | 19.4 | 6.97 | 7.2 | 760 | 780 | 480 | 380 | 370 | 0.28 |
| TON-17 | - | 19.5 | 7.45 | 7.7 | 671 | 700 | 400 | 250 | 260 | 3.7 |
| TON-18 | - | 21.8 | 7.41 | 7.0 | 403 | 410 | 230 | 180 | 190 | 0.80 |
| TON-20 | - | 17.1 | 7.89 | 7.7 | 584 | 580 | 350 | 250 | 260 | 0.82 |
| TON-21 | TDS | 19.2 | 7.20 | 7.3 | 1095 | 1100 | 720 | 390 | 390 | 0.21 |
| TON-22 | - | 14.2 | 7.89 | 7.7 | 402 | 410 | 230 | 200 | 190 | 1.1 |
| TON-23/23D | - | 19.7 | 7.22 | 7.3 | 773 | 805 | 480 | 365 | 380 | 0.22 |
| TON-24/24S | - | 17.2 | 7.90 | 7.75 | 319 | 335 | 195 | 145 | 140 | 0.02 |
| TON-25/26 | As, NO ₃ , TDS | 21.4 | 7.21 | 7.35 | 1343 | 1400 | 825 | 570 | 575 | 0.05 |
| TON-27 | - | 21.8 | 7.80 | 7.4 | 359 | 380 | 220 | 100 | 100 | 0.23 |
| TON-3/28/32 | Cd, Th* | 12.2 | 7.47 | 7.88 | 116 | 120 | 78 | - | 67 | 1.7 |
| TON-29 | - | 16.2 | 7.21 | 8.09 | 701 | 720 | 420 | - | 400 | 0.20 |
| TON-30 | - | 12.4 | 7.75 | 8.17 | 356 | 370 | 240 | - | 200 | 2.7 |
| TON-31 | - | 11.9 | 7.70 | 7.59 | 467 | 490 | 310 | - | 250 | 2.4 |
| TON-3/28/32 | - | 12.1 | 7.30 | 7.33 | 125 | 130 | 64 | - | 67 | 1.3 |
| TON-33 | - | 11.8 | 7.49 | 7.56 | 177 | 190 | 98 | - | 98 | ND |

italics = constituent exceeded holding time

bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

* Cadmium and thallium were apparently introduced to the water sample from recent concrete work at the water source.

Appendix B. Groundwater Quality Data, Tonto Creek Basin, 2002-2012---Continued

| Site # | T. Nitrate-N (mg/L) | Nitrite-N (mg/L) | TKN (mg/L) | Ammonia (mg/L) | T. Phosphorus (mg/L) | SAR (value) | Irrigation Quality | Aluminum (mg/L) | Strontium (mg/L) |
|-------------|------------------------|---------------------|---------------|-------------------|-------------------------|----------------|-----------------------|--------------------|---------------------|
| TON-1/1D | 0.62 | ND | ND | ND | ND | 0.2 | C2-S1 | ND | - |
| TON-2/2S | ND | ND | ND | ND | ND | 0.3 | C2-S1 | ND | - |
| TON-3/28/32 | 0.10 | ND | ND | ND | 0.040 | 0.1 | C1-S1 | ND | - |
| TON-5 | 0.033 | ND | ND | ND | 0.070 | 0.1 | C2-S1 | ND | - |
| TON-6 | 0.14 | ND | 0.068 | 0.045 | ND | 0.2 | C2-S1 | ND | - |
| TON-7 | 0.16 | ND | ND | ND | ND | 0.7 | C1-S1 | ND | - |
| TON-8 | 0.25 | ND | ND | ND | ND | 0.7 | C1-S1 | ND | - |
| TON-9 | 0.44 | ND | 0.072 | ND | 0.022 | 0.1 | C2-S1 | ND | - |
| TON-10/11 | 0.14 | ND | ND | ND | 0.034 | 2.0 | C3-S1 | - | - |
| TON-12 | 0.45 | ND | ND | ND | 0.029 | 1.9 | C3-S1 | - | - |
| TON-13/14 | ND | ND | ND* | ND | ND | 16.0 | C3-S3 | - | - |
| TON-15 | 0.19 | ND | ND | ND | 0.027 | 1.1 | C2-S1 | - | - |
| TON-16 | 0.59 | ND | ND | ND | ND | 0.5 | C3-S1 | - | - |
| TON-17 | 1.1 | ND | ND | ND | 0.037 | 1.3 | C2-S1 | - | - |
| TON-18 | 0.31 | ND | 0.82 | 0.37 | 0.056 | 0.4 | C2-S1 | - | - |
| TON-20 | 0.19 | ND | 0.071 | ND | 0.028 | 0.7 | C2-S1 | - | - |
| TON-21 | 0.66 | ND | ND | ND | 0.023 | 1.8 | C3-S1 | ND | - |
| TON-22 | ND | ND | ND | ND | 0.034 | 0.3 | C2-S1 | ND | - |
| TON-23/23D | 0.275 | ND | ND | ND | ND | 0.6 | C3-S1 | ND | - |
| TON-24/24S | 0.63 | ND | 0.11 | ND | ND | 0.5 | C2-S1 | ND | - |
| TON-25/26 | 28.5 | ND | 0.205 | ND | 0.073 | 1.3 | C3-S1 | ND | - |
| TON-27 | 0.45 | ND | ND | ND | ND | 1.9 | C2-S1 | - | - |
| TON-3/28/32 | ND | ND | ND | ND | ND | 0.1 | C1-S1 | ND | ND |
| TON-29 | ND | ND | ND | ND | ND | 0.3 | C2-S1 | ND | 0.28 |
| TON-30 | ND | ND | ND | ND | ND | 0.1 | C2-S1 | ND | 0.17 |
| TON-31 | ND | ND | ND | 0.10 | ND | 0.3 | C2-S1 | ND | 0.12 |
| TON-3/28/32 | ND | ND | 0.17 | ND | ND | 0.1 | C1-S1 | ND | ND |
| TON-33 | ND | ND | ND | ND | ND | 0.0 | C1-S1 | ND | ND |

italics = constituent exceeded holding time

bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Tonto Creek Basin, 2002-2012---Continued

| Site # | Iron (mg/L) | Lead (mg/L) | Manganese (mg/L) | Mercury (mg/L) | Nickel (mg/L) | Selenium (mg/L) | Silver (mg/L) | Thallium (mg/L) | Zinc (mg/L) |
|-------------|----------------|----------------|---------------------|-------------------|------------------|--------------------|------------------|--------------------|----------------|
| TON-1/1D | ND | ND | ND | ND | ND | ND | ND | ND | 0.22 |
| TON-2/2S | ND | 0.00765 | ND | ND | ND | ND | ND | ND | 0.85 |
| TON-3/28/32 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-5 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-6 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-7 | ND | ND | ND | ND | ND | ND | ND | ND | 0.070 |
| TON-8 | ND | ND | ND | ND | ND | ND | ND | ND | 2.4 |
| TON-9 | 0.14 | ND | 0.15 | ND | ND | ND | ND | ND | ND |
| TON-10/11 | 0.11 | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-12 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-13/14 | ND | ND | ND | ND | ND | ND | ND | ND | 0.235 |
| TON-15 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-16 | ND | ND | ND | ND | ND | ND | ND | ND | 0.053 |
| TON-17 | ND | ND | ND | ND | ND | ND | ND | ND | 1.1 |
| TON-18 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-20 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-21 | ND | ND | ND | ND | ND | 0.0058 | ND | ND | ND |
| TON-22 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-23/23D | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-24/24S | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-25/26 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-27 | ND | ND | ND | ND | ND | ND | ND | ND | 0.096 |
| TON-3/28/32 | 0.068 | 0.013 | ND | ND | ND | ND | ND | 0.013 | ND |
| TON-29 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-30 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-31 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-3/28/32 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| TON-33 | ND | ND | ND | ND | ND | ND | ND | ND | ND |

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bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Tonto Creek Basin, 2002-2012---Continued

| Site # | MCL Exceedances | Temp (°C) | pH-field (su) | pH-lab (su) | SC-field (µS/cm) | SC-lab (µS/cm) | TDS (mg/L) | Hard (mg/L) | Hard - cal (mg/L) | Turb (ntu) |
|--------|-----------------|-----------|---------------|-------------|------------------|----------------|------------|-------------|-------------------|-------------|
| TON-34 | As | 17.8 | 8.92 | 7.82 | 494 | 530 | 340 | 240 | - | <i>0.21</i> |
| TON-35 | | 23.7 | 7.41 | 7.21 | 563 | 570 | 330 | 270 | - | 0.98 |
| TON-36 | | 31.6 | 7.43 | 7.58 | 528 | 550 | 290 | 220 | - | ND |
| TON-37 | As | 23.1 | 7.85 | 8.28 | 585 | 620 | 370 | 270 | - | ND |
| TON-38 | | 16.5 | 7.39 | <i>7.33</i> | 597 | 600 | 370 | 340 | - | 0.22 |

italics = constituent exceeded holding time

Appendix B. Groundwater Quality Data, Tonto Creek Basin, 2002-2012---Continued

| Site # | Calcium (mg/L) | Magnesium (mg/L) | Sodium (mg/L) | Potassium (mg/L) | T. Alk (mg/L) | Bicarbonate (mg/L) | Carbonate (mg/L) | Chloride (mg/L) | Sulfate (mg/L) |
|--------|----------------|------------------|---------------|------------------|---------------|--------------------|------------------|-----------------|----------------|
| TON-34 | 78 | 11 | 34 | ND | 260 | 317 | ND | 12 | 13 |
| TON-35 | 79 | 17 | 30 | ND | 210 | 256 | ND | 47 | 25 |
| TON-36 | 65 | 15 | 34 | 2.2 | 190 | 232 | ND | 57 | 9.9 |
| TON-37 | 56 | 31 | 43 | 3.5 | 280 | 342 | ND | 26 | 16 |
| TON-38 | 96 | 23 | 17 | ND | 300 | 366 | ND | 17 | 7.7 |

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bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Tonto Creek Basin, 2002-2012---Continued

| Site # | T. Nitrate-N (mg/L) | Nitrite-N (mg/L) | TKN (mg/L) | Ammonia (mg/L) | T. Phosphorus (mg/L) | SAR (value) | Irrigation Quality | Aluminum (mg/L) | Strontium (mg/L) |
|--------|---------------------|------------------|------------|----------------|----------------------|-------------|--------------------|-----------------|------------------|
| TON-34 | ND | - | 0.47 | ND | ND | 1.0 | C2-S1 | ND | 0.26 |
| TON-35 | ND | ND | 0.13 | ND | ND | 0.9 | C2-S1 | ND | 0.57 |
| TON-36 | ND | ND | 0.16 | ND | ND | 1.0 | C2-S1 | ND | 0.32 |
| TON-37 | ND | ND | 0.26 | ND | ND | 1.1 | C2-S1 | ND | 0.92 |
| TON-38 | ND | ND | 0.12 | ND | ND | 0.4 | C2-S1 | ND | 0.22 |

italics = constituent exceeded holding time

bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level